# Johannes Peter Müller (1801-1858)

Anatomist and physiologist Johannes Müller inspired an entire generation of German scientists. Advocating microscopical research, chemical analysis, and physiological experimentation, he shaped the modern science of physiology and made Berlin one of Europe's leading centers for medical research. Müller's comparative anatomical studies revealed the functions of the nervous, sensory, endocrine, and reproductive systems. With his research trips and museum-building, he also helped to establish the science of oceanography.

Son of a Koblenz shoe-maker, Müller was born on July 14, 1801. Until Müller's fourteenth year, his region was run by France, and he benefited educationally when the Rhineland passed from French into Prussian hands in 1815. At the Koblenz Gymnasium, Müller's talents for mathematics and classical languages caught the attention of Prussian educational reformer Johannes Schulze, who convinced Müller's father to send him to the newly founded Bonn University instead of teaching him leather-work. Since 1818, Cultural Minister Karl Freiherr vom Stein zum Altenstein (1770-1840) had been working to make the Bonn University a showcase for Prussian Protestant scholarship, particularly in the natural sciences. He had preferentially hired Naturphilosophen, scholars who developed theories of nature based on elaborate analogies (Steudel 1963, p. 568; Finkelstein 1996, p. 78). Inspired by the philosophy of Friedrich Wilhelm Joseph von Schelling (1775-1854), Naturphilosophen believed that the order of nature corresponded to the structure of human consciousness and tried to discern patterns in natural structures, sometimes classifying animals by aligning them with human sensory systems. Müller began studying medicine at the Bonn University in the fall of 1819 and quickly embraced this approach to nature, earning his medical degree in 1822 with a doctoral thesis on the patterns of animal movement, especially in insects. His scientific strategy would soon change, however.

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Müller wanted to go to Paris to study with Georges Cuvier (1769-1832), Europe's leading comparative anatomist. Instead, the Bonn University Curator Philipp Jakob Rehfues granted him money to study with the Berlin anatomist Carl Asmund Rudolphi (1771-1832), who strongly criticized Naturphilosophie and advocated microscopic studies. Müller quickly became an adept microscopist, and when he passed his Prussian state medical exam and returned to Bonn in the winter of 1824, Rudolphi gave him his own Frauenhofer microscope to conduct his own research (Haberling 1924, p. 54). Müller remained in Bonn until 1833, rising from lecturer (1824) to Professor Extraordinarius (1826) to Professor Ordinarius (1830) and using the Frauenhofer instrument to perform an extraordinary number of physiological and anatomical studies.

On October 19, 1824, Müller delivered a lecture "Ueber das Bedürfnis der Physiologie nach einer philosophischen Naturbetrachtung" (On the Need of Physiology for a Philosophical Contemplation of Nature) in which he outlined a scientific strategy he would use for much of his life, combining close observation of natural forms with limited philosophical theorizing about their interrelations (Rothschuh 1973, p. 197). The question of whether Müller developed his comparative anatomy and physiology out of or in opposition to Naturphilosophie has raised considerable controversy (Hagner and Wahrig-Schmidt 1992). Müller opposed both empty theorizing and blind empiricism, advocating natural science based on close observation and philosophical pattern-seeking and systematization.

During his years in Bonn, Müller revealed crucial information about the visual, circulatory, endocrine, and reproductive systems. He rarely studied any function in one animal alone, preferring to compare the ways that different organisms solved physiological problems. His 1826 *Zur vergleichenden Physiologie des Gesichtssinnes des Menschen und der Thiere* (On the Comparative Physiology of Vision in Men and Animals) explained the mechanism of human binocular vision but also contained a long section on the structure of insect eyes. In this book, Müller first expressed his law of specific sense energies. Through his studies of nervous systems, Müller realized that nerves are not passive conductors of outer stimuli, since the same external event or mechanical pinch affects different nerves in different ways and can be perceived as light, sound, or pain. As he later put it in his *Handbuch der Physiologie des Menschen* (Elements of Physiology), “perception is not the conduction to our consciousness of a quality or circumstance outside of our body, but the conduction to our consciousness of a quality or circumstance of our nerves which has been caused by an external event” (Müller 1837, p. 780). Each nerve can respond to stimuli only in a specific way, so that our knowledge of the world reflects the structure of our nervous system.

In 1826, Müller also published *Ueber die phantastischen Gesichtserscheinungen* (On Fantasy Images), a study of visual hallucinations. Noticing that when he was falling asleep, he could sometimes see imaginary people and things, he tried to manipulate these figures in a series of rigorous self-experiments. His work showed that the visual system is active, not a passive recorder of external events. Unfortunately, the coffee-drinking and sleep-deprivation that these experiments demanded led to his first mental collapse. In April 1827, he married the gifted musician Nanny Zeiller, then broke down immediately afterward.

It has been claimed that Müller's depressive episodes in 1827, 1840, 1848, 1852, and 1855 were the results of an inherited manic-depressive condition (Steudel 1963, p. 26). In every case, however, his depression had a clear external cause. In 1827 Müller was exhausted from a full teaching load, extensive research, and the publication of two major books. The doctor who assessed his health for the Prussian government, his teacher Phillipp von Walther, found that he was suffering from "hypochondria", a term then commonly used for depression (Haberling 1924, p. 79). Within a year, Müller was able to resume his research, but he subsequently avoided self-experimentation.

Between 1828 and 1830, Müller conducted extensive comparative studies of the endocrine and reproductive systems, publishing *De glandularum secernetium* and *Bildungsgeschichte der Genitalien* in 1830. He demonstrated that glands, not blood vessels, secrete substances that control bodily functions, and he identified the blood vessels responsible for male erections. He then made one of his greatest contributions to physiology, the experimental demonstration of British physician Charles Bell's (1774-1842) and French physiologist François Magendie's (1783-1855) hypothesis that the dorsal roots of spinal nerves (those initially heading upward along the back) carry mainly sensory fibers, whereas the ventral ones (those initially heading downward toward the belly) carry mainly motor fibers. Bell had proposed the idea in 1811 but had provided no experimental evidence; Magendie had conducted experiments in 1822, but his live dogs were in such distress that his results were questionable. In 1831 Müller thought of repeating Magendie's experiments in frogs, hardier animals in which the spinal cord could be more readily exposed (Steudel 1963, p. 570). He not only confirmed Magendie's findings; he encouraged aspiring physiologists to repeat his experiments, publicizing a new system in which young experimenters could study the functions of muscles and nerves.

When Rudolphi died in 1832, Müller made an all-out effort to obtain his Berlin professorship of anatomy and physiology, the most prestigious one in the German territories. Having enjoyed the support of the Prussian Cultural Ministry for 15 years and having always taken care to publicize his discoveries, he knew that he had a chance to win the position and wrote to Cultural Minister von Altenstein describing his qualifications for the job. Müller's student, physiologist Emil Du Bois-Reymond, later called this a highly unusual step, but it was a fairly common practice at the time (Du Bois-Reymond 1887, pp. 184-85; Clark 1996). The Cultural Ministry first offered the job to anatomist Friedrich Tiedemann, but Müller received the position when Tiedemann turned it down. From 1833 until 1858, he worked to make Berlin a center for comparative anatomical studies, as he had promised to do in his self-nominating letter.

As a professor on Berlin's Medical Faculty, Müller influenced a tremendous number of students. Each winter semester, he taught human and sensory anatomy and ran the medical students' dissecting laboratory with his colleague Friedrich Schlemm. Every summer semester, he taught physiology, comparative anatomy, and pathological anatomy. He also examined all Prussian candidates seeking medical degrees. Among the students impressed by his teaching were Ernst Brücke (1819-92), Emil Du Bois-Reymond (1818-96), Ernst Haeckel (1834-1919), Hermann Helmholtz (1821-94), Robert Remak (1815-65), and Rudolf Virchow (1821-1902). Helmholtz and Virchow have left detailed notes on Müller's comparative anatomy and pathological anatomy lectures (Archiv der Berlin-Brandenburgische Anatomie der Wissenschaften, Nachlass Helmholtz 538; Nachlass Virchow 2803, 2804, 2805). Their notebooks show how Müller discussed ongoing microscopic research, offered students detailed drawings of structures, and compared the life functions of many different animals.

As soon as he arrived in Berlin, Müller began revitalizing the university's anatomical museum, which Rudolphi had built from Johann Gotlieb Walter's private collection, sold to the Prussian government in 1803 (Winau 1987, pp. 107-8). Housed on the second floor of the university building's west wing, the anatomical museum became Müller's greatest scientific love. He became obsessed with collecting all known animal forms, past and present, in hope that by aligning them properly, he could understand how life was organized. Each August and September, the only two months of the year in which he didn't teach, Müller traveled to the Baltic Sea, North Sea, or Mediterranean Sea coast to study marine organisms and collect new museum specimens.

Between 1833 and 1844, Müller consolidated his physiological knowledge in his enormously influential *Handbuch der Physiologie,* which became the leading textbook in the field for much of the nineteenth century (Lohff 1978, p. 247). The organization of this work shows Müller's simultaneous commitments to vitalism, philosophy, and rigorous science. He begins with a discussion of why organic matter differs fundamentally from inorganic but then proceeds to chemical analyses of the blood and lymph. He describes in detail the circulatory, lymphatic, respiratory, digestive, endocrine, nervous, and sensory systems in a wide variety of animals but explains that the presence of a soul makes each organism an indivisible whole. The same work that examines the behavior of light and sound waves proposes that living organisms possess a life-energy for which physical laws can never fully account.

To improve communication among German-speaking physiologists, Müller founded the *Archiv für Anatomie, Physiologie und wissenschaftliche Medicin* in 1834. His journal contained yearly reports on physiological and anatomical research throughout Europe and quickly became one of the most respected scientific periodicals. From 1834 onward, however, Müller's own research focused increasingly on observations of animal structures and less and less on their physiological functions. In 1838, he applied his student Theodor Schwann's (1810-82) cell theory to pathological studies, demonstrating in his work *Ueber den feineren Bau der krankhaften Geschwülste* (On the Fine Structure of Pathological Tumors, 1838) that tumors were made of cells. In one of his final physiological investigations, *Ueber die Compensation der physischen Kräfte am menschlichen Stimmorgan* (On the Compensation of Physical Forces in the Human Voicebox, 1839), he used a severed head and his wife's piano to study the way that the human voice produces particular tones.

The project that consumed most of Müller's energy and attention was the classification of marine organisms. In the late 1830s, he developed a new classificatory system for the myxinoids (hagfishes) and plagiostomes (cartilaginous fishes such as sharks). In the 1840s, he continued this work with studies of the cyclostomes (lampreys) and ganoid (scaly) fishes. Müller was particularly intrigued by echinoderms, animals with radial symmetry such as sea-urchins and starfish. On his research trips, he used a net he had specially designed to scoop floating echinoderm embryos from the sea surface, a technique that he called "pelagic fishery" (Rheinberger 1998). Müller focused on organisms that fell along the borders of previous classificatory systems, attracted by the challenge they presented. He suffered a serious depressive episode in 1852 when he discovered what appeared to be slugs developing in the gut cavities of sea-cucumbers, since the classificatory system he had been developing could not account for the appearance of one organism inside of another.

Müller never undertook his research trips alone, delighting in his young students' company. Ernst Haeckel shared Müller's fascination with animal forms and enjoyed fishing with him, but the same cannot be said for all of Müller's pupils (Haeckel 1921, pp. 123-25). From the time that Müller arrived in Berlin, he invited gifted students to work with him, sharing his microscopes and preparations. He never had a "lab" in the modern sense of a continuous space with an adjacent office. Until the 1860s, universities in the German territories rarely assigned scientists on-site facilities to dissect specimens and perform experiments. At first, the best that Müller could offer students who wanted to begin their own investigations was two small rooms adjacent to the medical students' dissecting hall at the Anatomical Institute, located behind the Garnisonkirche. The reports of Friedrich Bidder and Emil Du Bois-Reymond reveal how dark, cramped, and foul-smelling those workrooms were (Bidder 1934, p. 62; Du Bois-Reymond 1887, p. 193). Once the west wing of the university building was renovated in the mid-1830s, Müller began installing students with scalpels and microscopes in odd corners of the anatomical museum, where Du Bois-Reymond conducted experiments and began a makeshift Physiological Institute in the 1850s. Müller and his students also worked in their own living quarters. Jakob Henle and Theodor Schwann studied microscopic preparations at their boarding house at the corner of Mohrenstrasse and Friedrichstrasse, and Du Bois-Reymond measured the electrical activity of frogs' nerves and muscles in his apartment near the Veterinary School (Merkel 1891, p. 138; Dierig n.d.).

In addition to teaching and performing research, Müller performed burdensome administrative duties. He served as Dean of the Medical Faculty in 1835-36 and 1842-43 and Rector of the Berlin University in 1838-39 and 1847-48. This last term proved truly unfortunate, since in March 1848 when Berlin's citizens fought Prussian troops at the barricades, Müller became directly responsible for mediating between radical students (led by two of his brightest former pupils, Rudolf Virchow and Robert Remak) and the Prussian King. A conservative at heart, Müller felt loyal to the Prussian Cultural Ministry that had facilitated his career, and he feared that the liberals' and radicals' attempts to create democracy would bring poverty and social chaos. He also worried that an angry mob would loot the university building and destroy his precious anatomical museum. Du Bois-Reymond claims that Müller personally stood guard "with his sword girded" at the university gate, but his dramatic account seems over-exaggerated (Du Bois-Reymond 1887, p. 275). Twice Cultural Minister von Ladenberg summoned Müller and scolded him for failing to control the rebellious students, threatening government intervention if Müller could not make them behave (Lenz 1910, pp. 250-53). Rudolf Virchow declared that Müller was "no politician," the worst possible man for such a sensitive job (Virchow 1858, p. 37). As soon as the semester ended, Müller suffered another paralyzing depression and was unable to resume his research until the spring of 1849.

Müller underwent a final depressive bout, from which he never fully recovered, after a traumatic shipwreck in September, 1855. While returning from a research trip to Sweden, he was hurled into the Baltic Sea when his steamship sank, and he survived only by clinging to a piece of wreckage (Haberling 1924, pp. 426-29). A young student who had accompanied him drowned, and he felt personally responsible for the pupil's death. Although Müller continued his teaching and research after this incident, his health began to fail. He took opium to alleviate abdominal pains and combat the insomnia that had plagued him for most of his life. Since his students' accounts of his untimely death on April 28, 1858 vary so greatly, it is impossible to be sure of its cause. Du Bois-Reymond claims that Müller died unexpectedly of "the rupture of a great vessel"; Virchow, that he felt his death coming on and prepared for it by summoning his son (Du Bois-Reymond 1887, p. 298; Virchow 1858, p. 38). Ernst Haeckel, however, speculated that Müller took his own life, pointing out how depressed his teacher had become (Haberling 1924, pp. 450-51).

Müller's depression in the 1850s resulted from his waning confidence in pelagic fishery and his accumulation and ordering of animal forms. Müller never believed that species had evolved over time, and he died before the publication of Charles Darwin's *Origin of Species* (1859), which suggested a "great plan of life" according to which he might have organized his museum. His students' accounts of his personality and scientific style vary so greatly because they serve the pupils' own interests, constructing Müller as a precursor who raised questions but failed to answer them because he lacked the insights that they developed through their own work (Jardine 1997, p. 302). Du Bois-Reymond wrote that Müller's vitalism and quest for a grand plan prevented any real commitment to rigorous physiological research, such as his own studies of animal electricity (Du Bois-Reymond 1887, p. 222). Ernst Brücke and Hermann Helmholtz largely shared this view. Ernst Haeckel claimed that Müller would have embraced evolutionary theory, which would have allowed him to solve the "riddle" of life's varying forms—something that Haeckel believed he had accomplished in his best-selling work, *The Riddle of the Universe* (1901).

Müller's scientific value is best assessed through the extraordinarily diverse work of these critical students, achievements in anatomy, histology, pathology, embryology, neurophysiology, and physics. As a teacher, he espoused the romantic notion of life-force but encouraged students to investigate any interesting structure or phenomenon. While he never discovered the "great plan of life," he inspired a generation of researchers to explore life's wonders.

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